Studies Supporting Radiation Hormesis

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Radiation Exposure Studies Supporting Hormesis

- Radium Dial Painters
- Atomic Bomb Survivors
- Nuclear Shipyard Workers
- Other Nuclear Workers
- Canadian Fluoroscopy Study
- Non-Hodgkin’s Lymphoma Trial
- Taiwan Apartment Dwellers

Radium Dial Painters

Radium Dial Painters

- In 1925 it was reported that[28]
  - After tipping brushes with their lips for 5 years, 18 female radium dial painters received high total absorbed radiation doses and developed necrosis (cell death) of jaw bones and pernicious anemia*
  - Other high-dose recipients developed possible osteosarcomas (bone tumors)
- 30-year follow-up of 1155 low-dose radium dial painters showed lower cancer *incidence* than general population and longer life span[28]

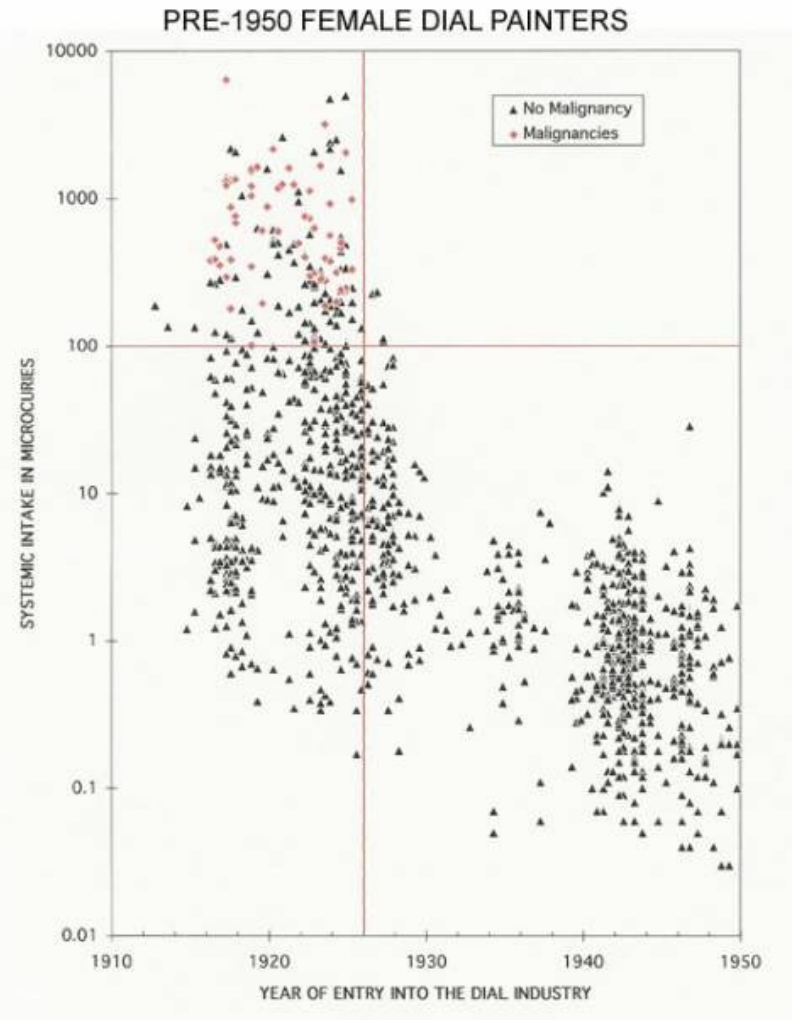
* Severe anemia associated with failure to absorb vitamin B_{12} and characterized by presence of abnormally large red blood cells, gastrointestinal disturbances, and lesions of the spinal cord

Radium Dial Painters (cont.)

- No observed excess *incidence* of bone cancers in radium dial painters when total absorbed dose (chronic) below 10 Gy[30] (10 Sv or 1000 rem)
- Except for breast cancer, other cancer *mortality* rates showed no change from general population[8]
- Observed breast cancer *mortality* rates showed no dependency on total absorbed dose[8]
- Leukemia *mortality* in U.S. female radium dial painters much lower than expected[9]
- No leukemia *deaths* and increased average lifespan found in British female dial painters who had worked 2-50 years with radium[10]

Radium Dial Painters (cont.)

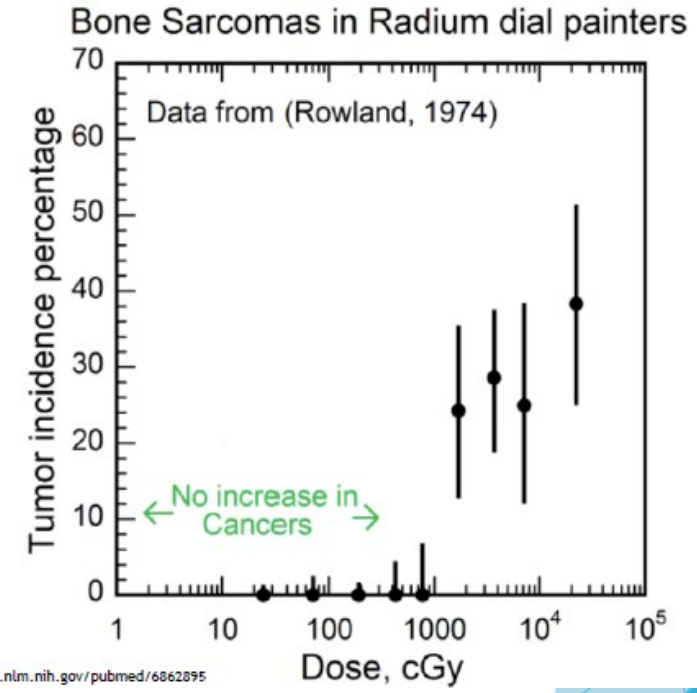
- In 1981, Dr. Robley Evans of MIT reported that in thousands of radium dial painter cases worldwide, still no occurrences of bone cancer or nasal carcinoma in individuals who ingested less than 250 microcuries of radium-226 (produced estimated total absorbed dose of 1,000 rad (10 Gy) to bone)[11]
- In 1997, Dr. Robert Rowland presented radium-induced cancer data based on very reliable body count measurements for population of 2,383 cases[13]
  - All 64 occurrences of bone sarcoma (tumor) occurred in 264 cases with more than 10 Gy exposure
  - No sarcomas appeared in 2,119 radium cases with less than 10 Gy exposure



Ref. Rowland, R.E., *Radium in Humans: A Review of U.S. Studies*. Argonne National Laboratory, Argonne Ill. (1994)

64 malignancies in **2383** dial painters

56 radium dial painters' bone sarcomas occurred at a threshold over ~ 10,000 mGy. (1412 unharmed)



http://journals.lww.com/health-physics/Abstract/1974/11000/Radium_in_Man_.10.aspx

http://www.ncbi.nlm.nih.gov/pubmed/6862895

Atomic Bomb Survivor Data

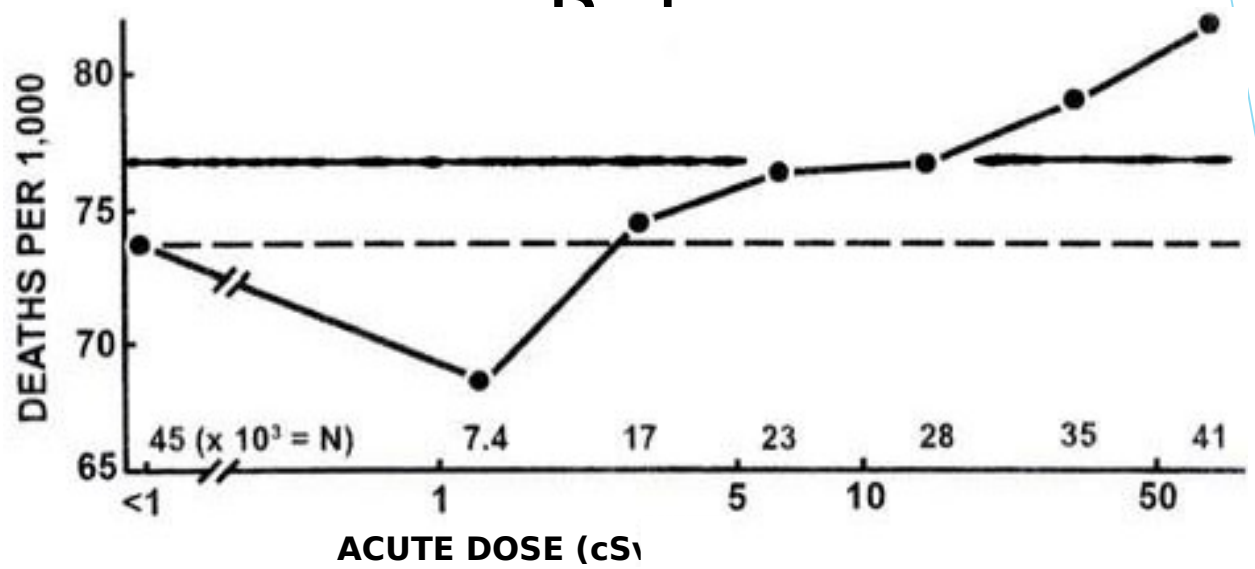
Atomic Bomb Survivors

- Conclusions about the effects of acute radiation exposure generally based on data from Japanese atomic bomb survivors
- Acute exposures exemplified by 86,520 Japanese survivors of atomic bomb explosions[14]
  - Survivor cancer *mortality* compared with that of people 3-10 km from ground zero ("in-the-city" control population) and unexposed people in villages northwest of Hiroshima ("out-of-city" control population)
  - "In-the-city" control population received some radiation from bombs as well as residual radiation from entering area inside 3 km radius from ground zero

Atomic Bomb Survivors (cont.)

- Cancer *mortality* rate of 7,430 survivors who received 1-1.9 cSv, less than that of both control populations (next slide graphic)
- 28,423 survivors who received <20 cSv had 76.6 cancer deaths per 1,000 people
  - Close to *mortality* rate for “out-of-city” control population (77 cancer deaths per 1,000 people)
- Survivor exposures >20 cSv showed increased cancer death rates relative to “out-of-city” control population commensurate with increasing dose

Atom Bomb Survivor Cancer Mortality



(Numbers above abscissa indicate thousands of people included in each point; i.e. the number receiving a dose ≤ *x*. **Dashed and solid horizontal lines represent mortality rates for "in-the-city" and "out-of-city" control populations, respectively.**)

Ref. *Biological Effects of Ionizing Radiation: a Perspective for Japan*, T.T. Luckey, Jour.
of Amer. Phys. and Surg., Vol. 16 No. 2, Summer 2011

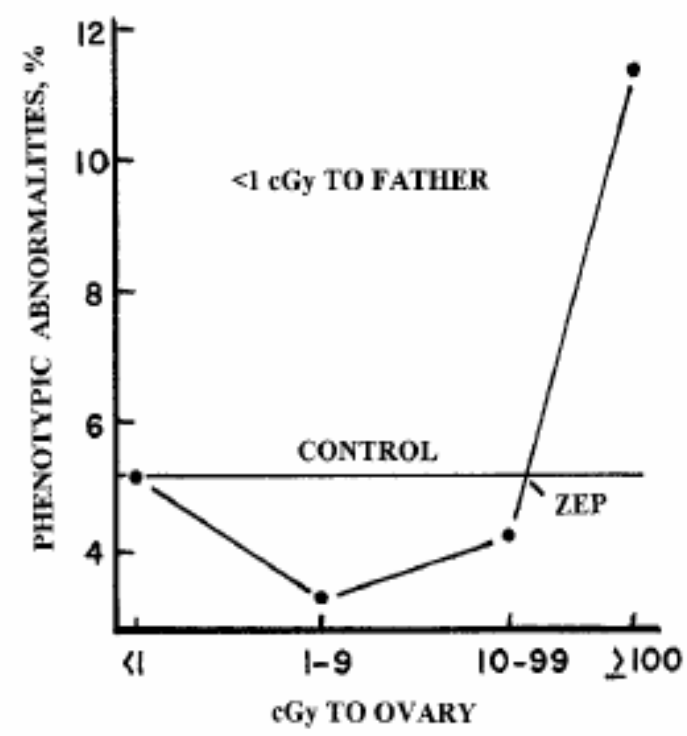
Atomic Bomb Survivors (cont.)

- Later studies confirm reduced cancer *mortality*, reduced leukemia *mortality* and increased average lifespan of Japanese atomic bomb survivors[15]
- Among those who received (acute) doses lower than 20 cSv (20 rem), no increase in number of total cancer deaths[16]
- *Mortality* caused by leukemia even lower at (acute) doses below 10 cSv (10 rem)[16]
- UNSCEAR-1958 leukemia *incidence* data clearly demonstrate threshold occurs at acute dose of ≈ 50 cSv (or 50 rem)[31]

Atomic Bomb Survivors (cont.)

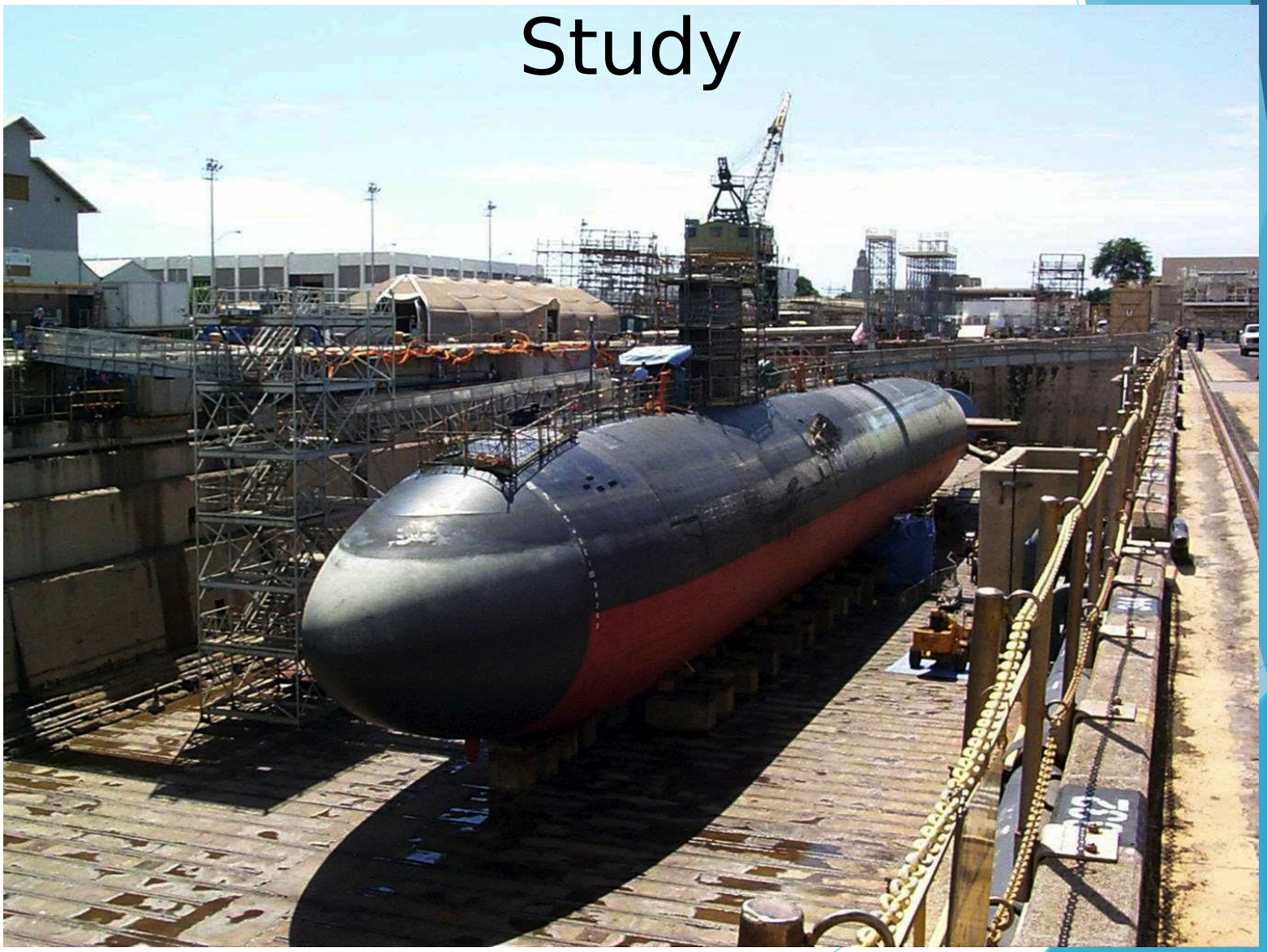
- Life expectancy of survivors found higher than in control groups, and no adverse genetic effects found in progeny of survivors[17]
- Low doses of ionizing radiation reduced genetic abnormalities
  - When both parents exposed to < 40 cGy, babies born to Japanese bomb survivors had 30% fewer molecular mutations and 33% fewer chromosomal aberrations than controls[15]
  - Genetic abnormalities significantly reduced in babies born of mothers who received < 20 cGy[18] (next slide graphic)
  - Exposure of Japanese fathers to low dose radiation (< 1 cGy) resulted in no significant effect on occurrence of genetic abnormalities in offspring[18]

Japanese Baby Genetic Abnormalities vs. Mother's Radiation Exposure



(Genetic abnormalities in Japanese babies were decreased in mothers exposed to low dose radiation (< 20 cGy) from atom bombs; control population had 5.2 abnormalities per 100 births.)

Nuclear Shipyard Worker Study



Nuclear Shipyard Workers

- One of largest and most thorough studies of effects of low-level (chronic) radiation on nuclear industry workers, Nuclear Shipyard Workers Study completed in 1987[19]
  - 10-year study of 39,004 nuclear workers matched with
    33,352 non-nuclear workers in naval shipyard
  - Workers in study exposed to external cobalt-60 radiation (neutron activation product [from Co-59] in pipes and valves of reactor coolant system)

Nuclear Shipyard Workers (cont.)

- Two exposed nuclear worker groups
  - High-dose (> 500 mrem cumulative dose effective)
  - Low-dose (< 500 mrem cumulative dose effective)
- High-dose group *mortality* rate was 76 percent that of non-nuclear workers in control group
- Low-dose group *mortality* rate was 81 percent that of non-nuclear workers in control group

Other Nuclear Workers

- Studies involving >7 million person-years of experience with nuclear workers provided consistent and convincing evidence that low doses of external ionizing radiation decrease total cancer *mortality* rates[2,3]
- In 1997 Dr. T.D. Luckey summarized major nuclear worker vs. non-nuclear worker studies for nuclear fuel cycle and nuclear weapons complex activities[20]
  - Cancer *mortality* rate for nuclear workers was 60 percent of rate in comparable non-nuclear workers (next slide data summary table)

Cancer Mortality Rates in Control and Exposed Nuclear Worker Populations

		Control/Exposed		
Study[a]	Dose[b] (mSv)	Population (x 10^3)	Deaths (per 10^3)	Exposed Pop. Deaths as % of Control Pop. Deaths
1	7	21/4	22.0/2.0	9.1
2	20	4.7/3.3	23.7/20.3	85.7
3	66	20.6/15.3	34.8/20.8	59.8
4	25	11.4/2.9	20.5/17.7	86.3

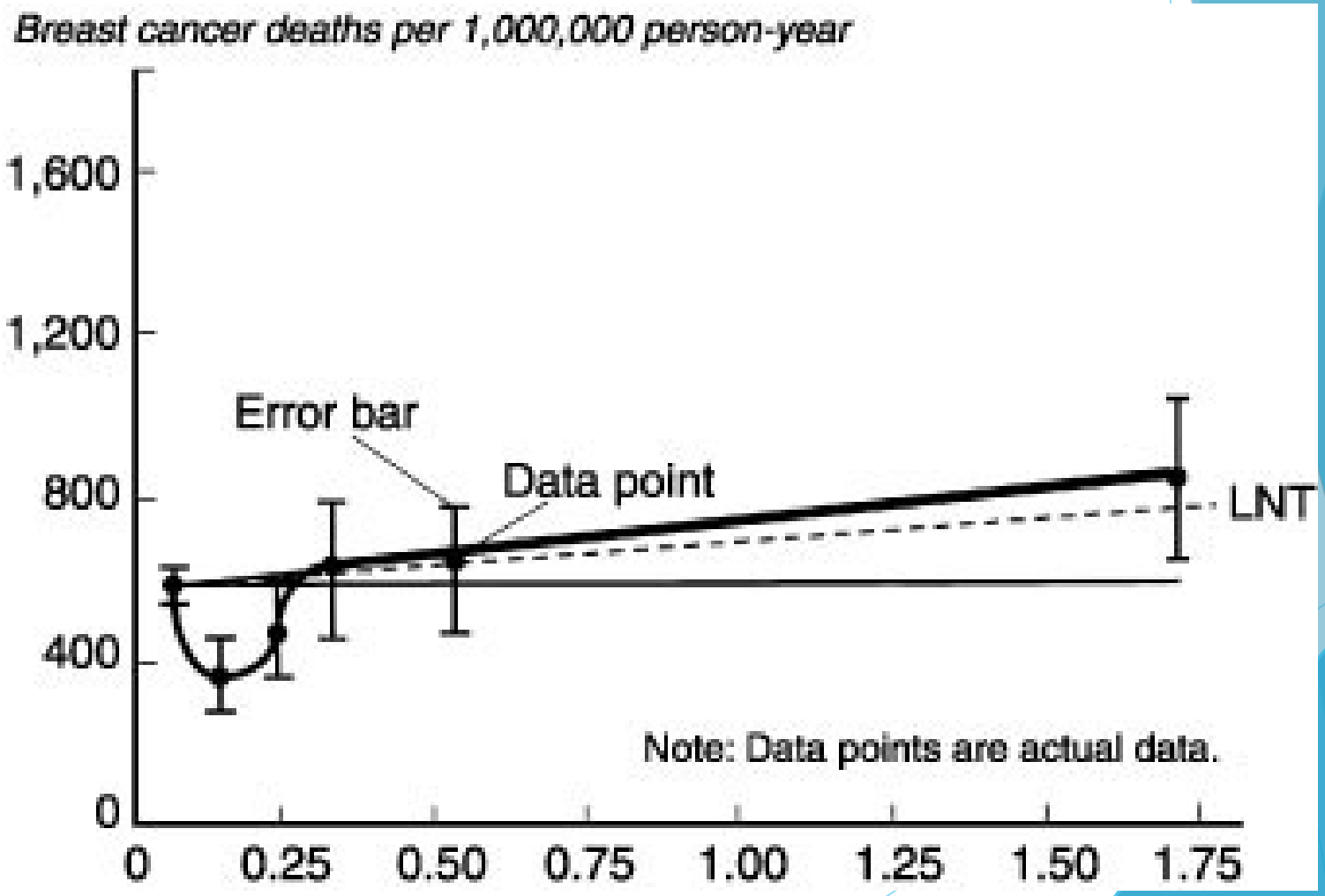
a. 1 – Nuclear Fuel Cycle Workers
   2 – Atomic Energy of Canada Limited Workers
   3 – Hanford/Oak Ridge/Rocky Flats Workers
   4 – Los Alamos Workers (incl. Pu exposure)
b. Estimated lifetime dose per exposed person

Canadian Fluoroscopy Study

Canadian Fluoroscopy Study

- 1989 study of breast cancer incidence in Canadian women being treated for tuberculosis with high fluoroscopy (x-ray) doses
- Acute exposures < 30 cGy showed statistically significant reduction in breast cancer[21] (next slide graphic)

Canadian Fluoroscopy Study Breast Cancer Mortality Rate vs. Dose

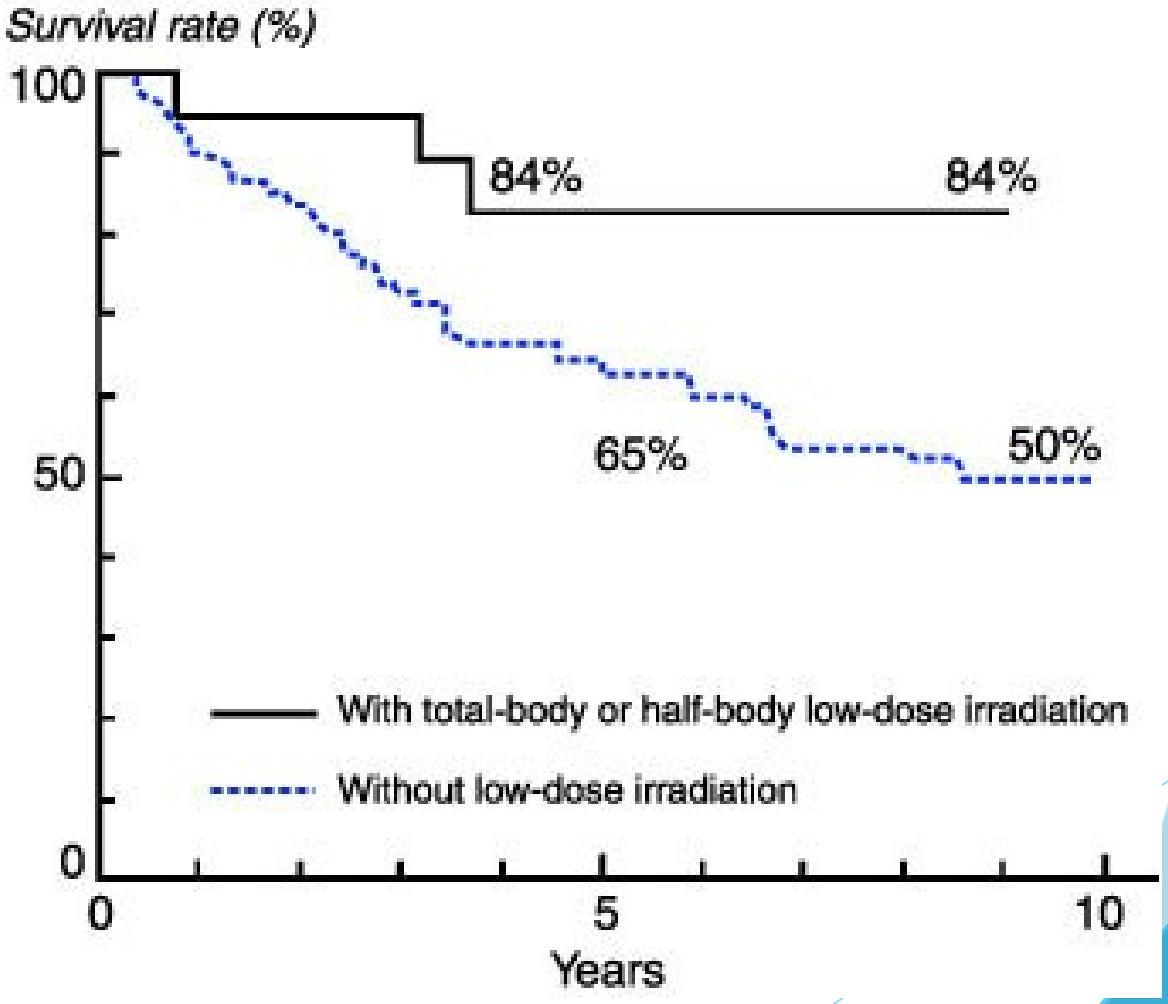


Non-Hodgkin's Lymphoma Trial

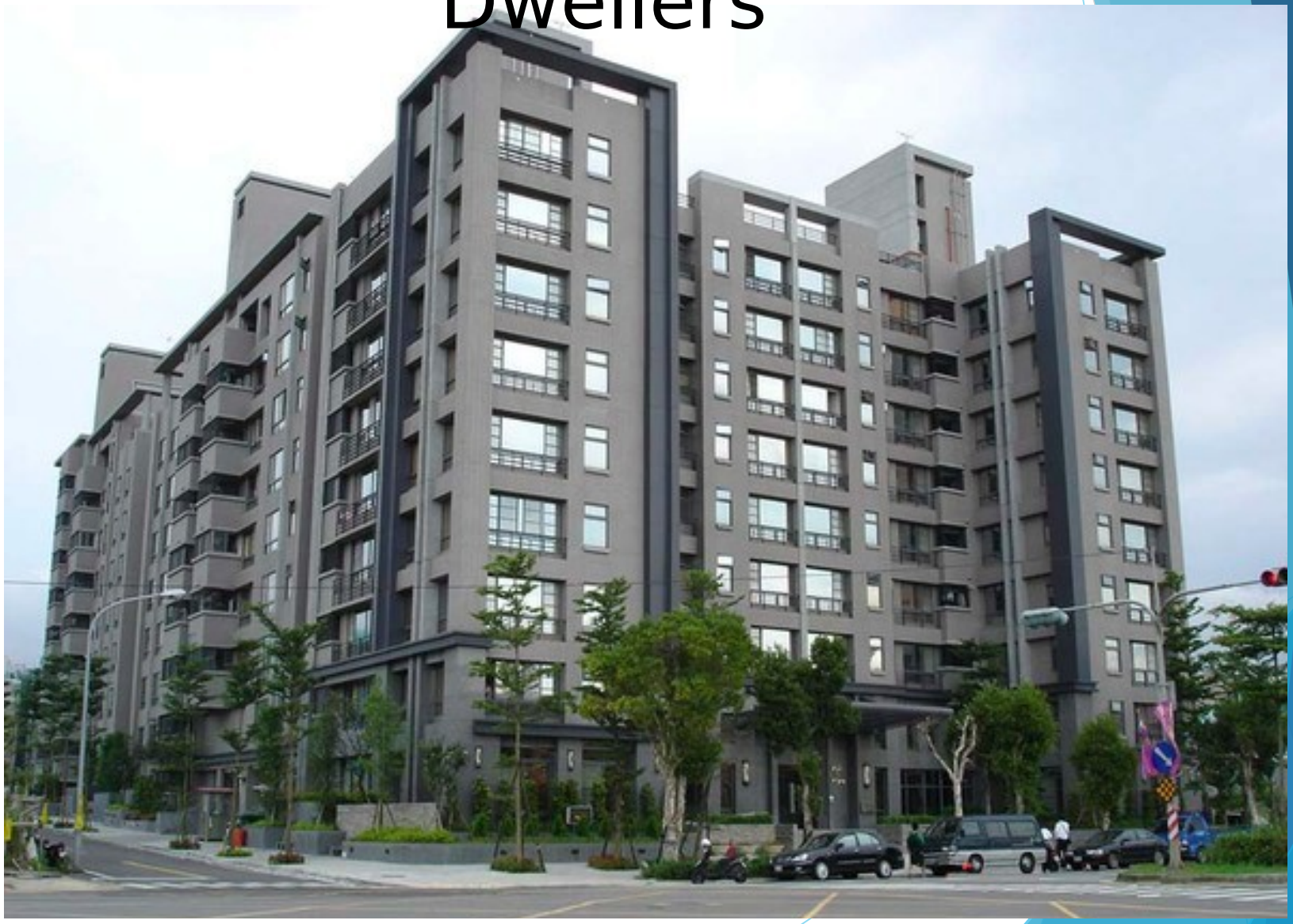
9-year clinical trial on non-Hodgkin's lymphoma patients confirmed that low-dose radiation group substantially outlived control group at 5 years and 10 years[23]

- 23 low-dose radiation patients and 94 control (unirradiated) patients with similar histological tumor grades
- Survival rate of low-dose radiation patients is 84 percent, compared with 50 percent survival of control patients at 10 years (next slide graphic)
- 12-year survival rate for low-dose patients remained at 84 percent

Non-Hodgkin's Lymphoma Trial Survival Rate[24]



Taiwan Apartment Dwellers



Further Evidence of Hormesis[25]

- Apartment buildings in Taipei City, Taiwan constructed with Co-60 contaminated materials
- 10,000 apartment dwellers received average collective dose of 400 mSv between 1983 and 2002 (20-year collective dose from natural U.S. background is ~70 mSv)
- Average dose in first year (1983) approximately 78 mSv, with individual doses ranging from 18 to 525 mSv

Further Evidence (cont.)

- Cancer death rate for exposed apartment population vs. general population of Taiwan (next slide graphic):
  - 20-year cancer *mortality* rate for apartment dwellers assessed to be 3.5 per 100,000 person- years[25,26]
  - Average spontaneous cancer death rate for general Taiwan population over same 20-year period is 116 deaths per 100,000 person-years[25,27]
- Births with congenital heart malformations:
  - Assessed to be 1.5 cases per 1,000 children for apartment population[25,26]
  - Based on partial official statistics and hospital experience, general population rate is 23 cases per 1,000 children[25,27]

Taipei City Apartment Dwellers Cancer Mortality Rate, 1983-2002[25]

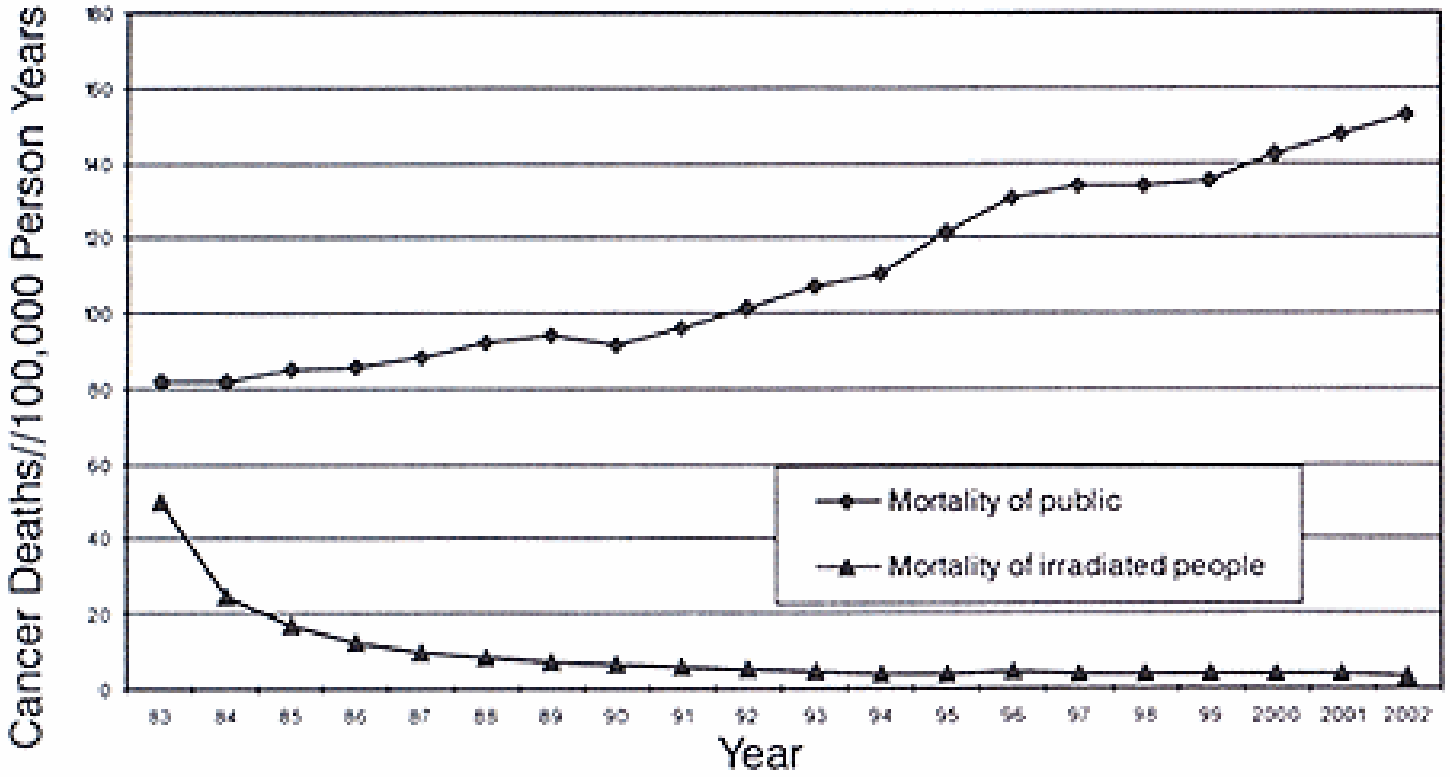


Figure 1. Cancer Mortality of the General Population and of the Exposed Population

Summary of Studies Providing Evidence to Support Radiation Hormesis

TABLE 1] Evidence Showing Reduction of Cancers Following Low-Dose Radiation or for a Threshold Dose for Cancer Induction

No.	Study Description	Observed Reduction of Cancers at Low Doses or Threshold Dose for Cancer Induction	Reference(s)
1	Study of second cancers in 5,000 survivors of childhood cancer who underwent radiation therapy and were followed up for an average of 29 y	Threshold dose for second cancers is approximately 5 Gy cumulative dose of fractionated radiation. Reduced second cancers per kg of tissue for regions that received a small dose (<50 cGy), when compared with nonirradiated regions	Tubiana et al[11]
2	Survival of patients with non-Hodgkin's lymphoma following radiation therapy	Reduced metastases and improved survival in patients subjected to fractionated total-body (or half-body) irradiation of 10 cGy or 15 cGy (for a cumulative dose of 1.5 Gy over 5 wk) in addition to standard radiation treatments to the tumor	Sakamoto[12]
3	Cancer incidence in Taiwan apartment residents exposed to radiation from contaminated building materials	Reduced total cancers in residents subjected to an average of approximately 5 cGy dose in comparison with age-matched control subjects	Hwang et al[13]; Doss[5]
4	Leukemia incidence in survivors of atomic bombing	Threshold dose of >approximately 50 cSv for increased leukemias	Cuttler[14]
5	Cancer mortality rates of population in villages near Mayak nuclear weapons facility	Reduced cancer mortality rates in population subjected to 12 cGy and 50 cGy dose of radiation	Kostyuchenko and Krestinina[15]
6	Breast cancer mortality rate in Canadian patients with TB who were subjected to fluoroscopy examinations	Reduced breast cancer mortality rate in patients with breast dose of approximately 15 cGy. Threshold dose of >50 cGy for increased breast cancer	Miller et al,[16] Pollycove[17]
7	Solid-cancer mortality rates in survivors of atomic bombing	Threshold dose of approximately 50 cGy for increased solid-cancer mortality rate. Reduced cancer mortality rates for lower doses (Fig 1)	Doss[5]
8	Lung cancers in residents of villages in Guam	Reduced lung cancers in residents subjected to approximately 3 cSv radiation dose (estimated using radon data) annually due to radon in their homes	Denton and Namazi[18]
9	Bone sarcomas in radium-dial painters	No increase in bone sarcomas for total dose <approximately 10 Gy accumulated over many years	Sanders[19]

Table 1 References

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Table 1 References (cont.)

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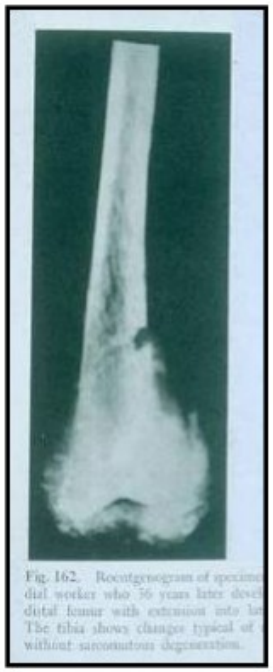
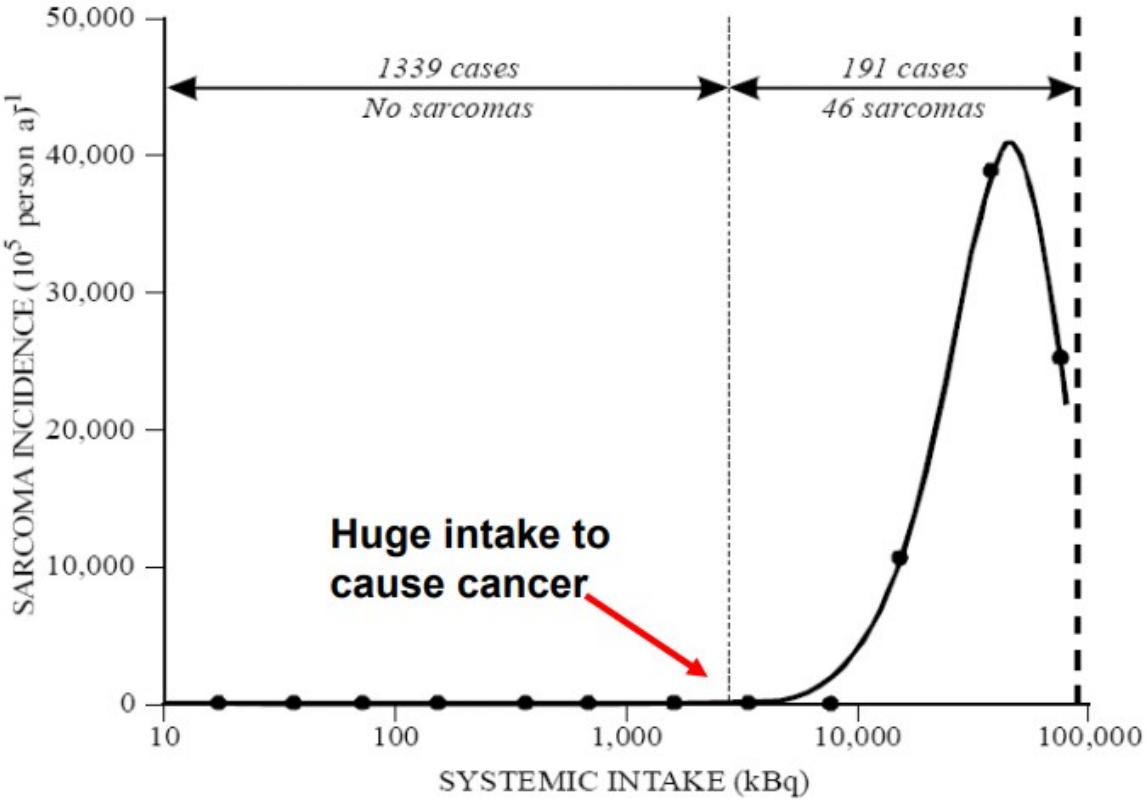
Supplemental Slides

Bone Cancer in Radium Dial Painters (UNSCEAR 2000; Rowland Rad Res 1978)

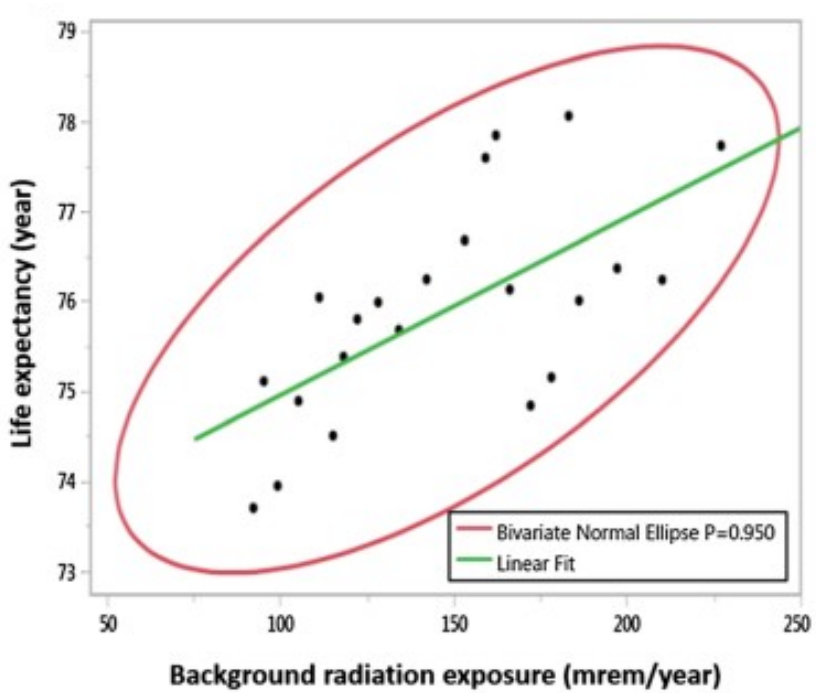




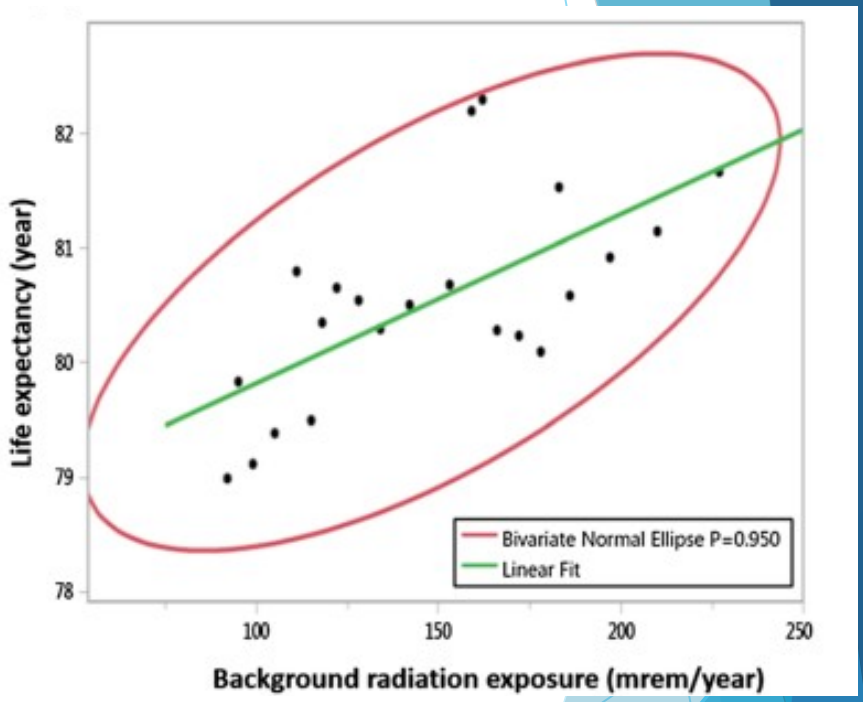
10 Gy suggested as a “practical threshold” for bone cancer

Bone Cancer, not leukemia

Life Expectancy vs Background Radiation Exposure

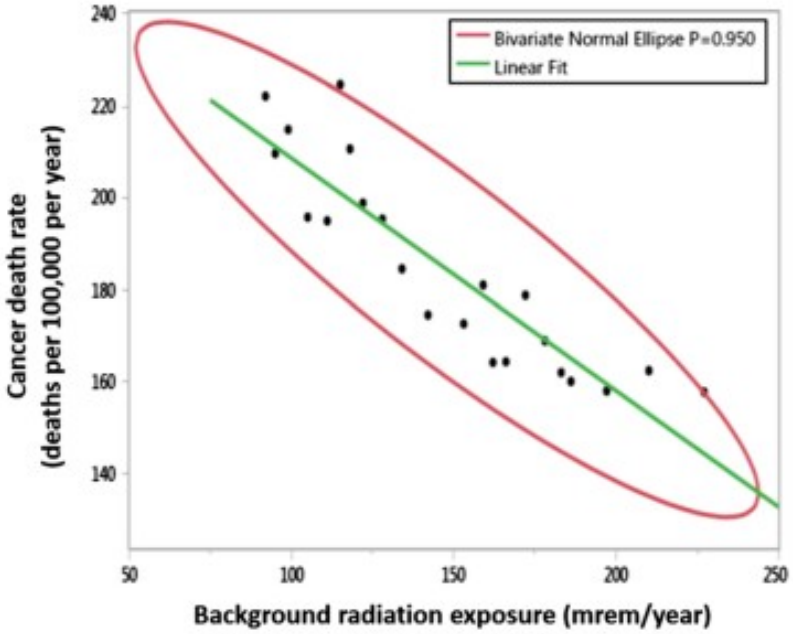


Males

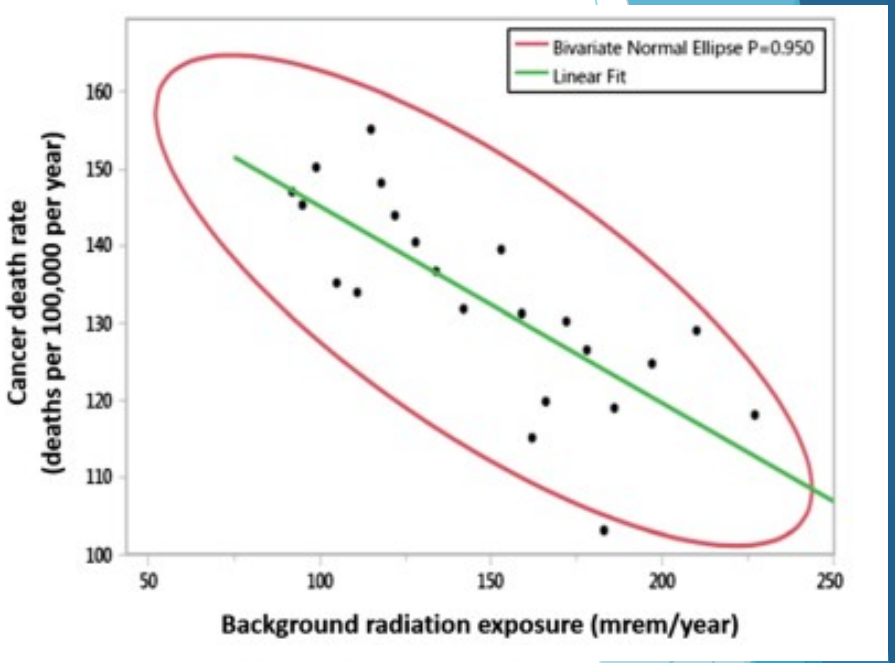


Females

Cancer Mortality vs Background Radiation Exposure



Males



Females